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New Domestic Locations:

Reconfiguring the home through the Internet of Things

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Abstract

This paper reflects on the reconstruction of the home as it becomes filtered through data that is streamed from smart objects. Retrofitting a home for The Internet of Things involves the placement of multiple sensors that record changes in conditions in order to construct a simulacrum of the actual house from which to analyse and form understandings of behaviour and in turn opportunities for connection.

This domestic data shadow (as it might be called) is not just a record of one inhabitant's activities within the house, but the sum of all of the activities of all parties. The single routines that constituted patterns of behaviour of personal habit and ownership become mixed in a single database that, without individual signatures, are lost and the house loses its cognitive architectures.

The paper explores the implications upon the occupants' sense of location as their model of home becomes reconfigured through the lens of a database. The paper draws upon findings of the Hub of All Things (HAT) project funded by the Research Council's UK Digital Economy Programme.

Introduction

Introduced in 1999, the term 'Internet of Things' is now beginning to make sense to businesses, organisations, and the general public as the flow of data between people, internet services and smart objects begins to influence the many products and systems that make up the world around us and support our daily life. The stepping stones toward living within a network society that were afforded by personal devices, from smart phones and tablets to personal health devices, were all extrapolations of a PC-based experience of the Internet. However, new smart objects are already beginning to become part of our habitual routines before they are even considered as computers. From bedside table lamps that are connected to

friends and families, to thermostats that tell you that you've left your heating on, data is transforming the relationship between people and objects.

In the past many IoT projects have used the network connection of artefacts to identify cost saving and process efficiencies (e.g., vehicle manufacturers), or to track goods within large networks (e.g., logistics companies), or to monitor the health and safety of systems (e.g., aircraft manufacturers). As these systems move from business-to-business, to business-to-consumer there is a significant push to build interoperable systems that will allow different branded 'things' to talk to each other across networks [1]. Within each of these cases the scale of data that is being streamed from devices and objects that are tagged with sensors is enormous. Data about performance including a host of parameters is streamed to databases that are growing at exponential rates:

"About 90% of all the data in the world has been generated in the past two years (a statistic that is holding roughly true even as time passes). There are about 2.7 zettabytes of data in the digital universe, where 1ZB of data is a billion terabytes (a typical computer hard drive these days can hold about 0.5TB, or 500 gigabytes). IBM predicts that will hit 8ZB by 2015." [2].

As networked objects become more common the amounts of data that they collect will soon outweigh what we know about the physical device. As artefacts share information with other artefacts around them, code can be written to interrogate their shared use. Machine learning is being used across a wide variety of databases to identify patterns in order to elicit new insights [3]. As these databases of objects intermingle with our own data shadows, it won't be long before the objects around us begin to make

suggestions and possibly become more reliable than our friends at telling us what is good or bad for us.

The complex constellations of material artefacts that are connected to everyday practices, data sets gathered in real-time, and algorithms that identify patterns constitute openings to new markets in which different kinds of value are exchanged. In many cases we are becoming attuned to understanding how value is constructed as we use software: social media users are becoming aware of the many pros and cons of exchanging *social values* in Facebook, while Trip Advisor users understand the implications of their liking, disliking and commenting upon the *economic values* of hotels.

However, as websites and apps become replaced by objects that we use in everyday life, such as making tea, taking a shower or getting on the bus, it is less clear how the flow of data that is derived from our interactions, constructs value and is ‘traded’ between services. This disjuncture in the flow of value represents new and emerging opportunities that are defining how we engage with cloud-based services. New markets are being developed that generate value between the social practices that constitute mundane aspects of our lives, and products and services that support them. From the Google Nest intelligent thermostat that learns how you live and promises to save you money and energy, to the Four Square and Swarm apps that encourages users to ‘checkin’ to places that they visit that helps build the databases of places that now appear in mapping applications such as Apple Maps. In both cases, the data produced through personal and social activities is exchanged into value to constitute new market content. Market models in which the rewards for sharing data come in one form, whilst the same data can be used by the service provider to build entirely different products for others.

Data Value Constellations

The term ‘data-value-constellations’ describes how, rather than existing in linear value-chains of production and consumption, artefacts are now part of networks. The term extends Normann and Ramirez’s [4] phrase ‘value constellations’, which describes the new economic patterns that emerged at the end of the 20th century as globalisation and new technologies suggested new ways to create value. Recognising the role of co-creation of value within networks, Normann and Ramirez highlight that “successful companies conceive of strategy as systematic social innovation: *the continuous design and redesign of complex business systems*” [4]. Within these systems, value-chains that mapped the linear passage of products are being superseded by complex social and environmental

connections as the passage of data becomes as important as the passage of the physical object.

Recent research in value creation has explored how value and worth is produced and diminished as individuals interact with services[5]. Due to the increasing accumulation of data that is attached to services it is possible to start examining how concepts of value change as participants engage with ‘contextual archetypes’ [6]. Contextual archetypes are familiar social activity sets that are recognisable and consist of material and immaterial systems, for example buying coffee at a local cafe. In their paper *Contextualization and value-in-context: How context frames exchange*, Chandler and Vargo describe how “individuals pursue value service-for-service exchanges that are the basis of dyads, triads, complex networks, and service ecosystems”[7]. This research has revealed how markets are constructed as individuals reconcile tensions across contexts to develop ‘service ecosystems’.

Writing on value and worth, Ng describes how new economic opportunities will increasingly capitalise upon social contexts that are becoming visible through the advent of ubiquitous computing [6]. Described as ‘contextual archetypes’ Ng suggests that, within the Internet of Things, objects change their role from being symbolic and functional to becoming agents within markets. This radical shift from vertical lines of consumption to horizontal, means that objects within an IoT are elevated to a role of actors within our networks of distribution and sharing.

As objects become online, it is likely that within any given social circumstance there will be very many markets operating as the network allows everybody to trade data according to the needs of the many people within that network. As the smart phones that we carry develop data about who we are, where we are, what we like, what we are in the proximity of, what we are using, and how we use it, new services will be offered in return for parts of our data. These experiences, whether we adopt them as care and play services, cheap deals or the provision of products, will constitute our experience of the cloud, and any aesthetic should be considered at the point of physical interaction.

Design Intervention:

Toilet Roll Paper as market

Through the summer of 2014, the author and his family was the subject of a study for a large consortium project that involved attaching sensors to parts of their own homes. As a member of the design team within the project, the author and team based in Edinburgh took on the task of developing a toilet roll holder that would record how much

toilet paper was on the existing roll that was in use, and send the data to an online database.

The toilet roll holder was considered an interesting subject of design and development because it could provide (on the surface) an easy case study of an instrumented product that would provide the project participant who owned it, personal data about toilet roll consumption. The assumption was that this unique and very personal data would place the participant in a position of power in a new market – that of providing data about the use of toilet roll. Whilst this may sound trivial, toilet paper can be considered a staple requirement of many western homes and at present the business model for distribution is simply for manufacturers to pass them to shops for sale. The hypothesis for building the smart toilet roll holder was that knowing more about the consumption of toilet roll paper could inform the distribution, manufacture and purchase of toilet rolls (in a similar way to the Just-In-Time model developed by Toyota in the 1970's [8]).

From the 5th of April to the time of authoring this paper, the amount of toilet roll in one toilet of the authors house has been available on the internet: <http://dev.modusdeus.com/toilet/vis/>. The instrumented toilet roll holder was constructed using the Electric Imp cloud service and embedded hardware and software platform, featuring an infrared sensor to detect the amount of paper that was on the roll – see Figure 1. As more toilet paper was used, the distance between the paper and roll, which sat on a spindle, grew. Figure 2 demonstrates the use of toilet roll paper, with drops in data associated with the use of paper.



Figure 1. First working prototype of the instrumented toilet roll holder. © Chris Speed.

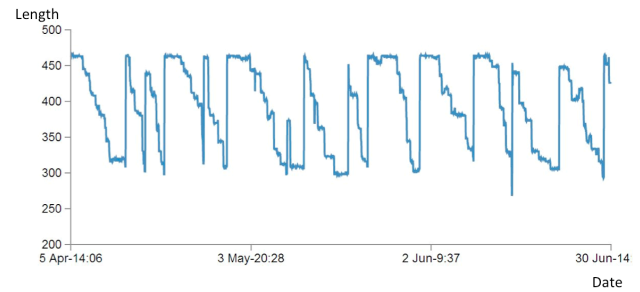


Figure 2. An example of output of the toilet roll holder. Full toilet rolls can be identified as having the highest value up the Y axis, and significant use of the toilet roll can be identified in the drops in data. © Chris Speed.

Living with the toilet roll holder and its data however proved to be far more disruptive than anticipated, and although it is early days before the research project understands how such personal data contributed to building a domestic market for selling data, the social impact was significant.

Originally identified by the research team as an easy 'smart' object to build compared to fridges and other domestic containers which hold multiple products, the toilet roll is at the centre of highly personal practices that take place behind locked doors. Through the online graph it is possible to clearly identify events that use significant amounts of toilet paper from which it is further possible to infer particular toilet activities see Fig. 3. Upon further analysis the graph revealed to the author and his family (all of whom have agreed to the study and to the sharing of the data), a series of likely events including cleaning up after cats, the running out of toilet paper, extra house guests and somebody having a runny nose.

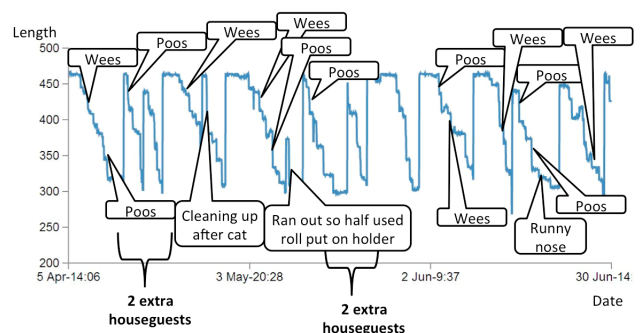


Figure 3. Toilet roll data with estimates of usage patterns by householders. © Chris Speed & Glenn Parry.

Although the members of the family are quite happy to give the data away, the same data when correlated with

other datasets could identify individuals and present a loss of privacy.

During the preliminary install of bathroom sensors in the authors' house a wireless passive infrared sensor was placed in the bathroom to detect the presence of people (Figure 4). When the device detects movement a small red LED lights on the surface of the object telling the occupant that they have been detected. Following ethical protocols during installation, the family was introduced to the sensor and their permission was sought to gather data. However when consulting the authors daughter (8) she posed the question: "can it see me on the toilet?". An apparently simple question and one that the author could only truthfully answer as "yes". However, the author proceeded to describe what the sensor could actually see, and once his daughter was happy that the device couldn't identify her in person, concern for the device passed.



Figure 4. *Wireless passive infrared sensor installed in authors bathroom during pilot period.* © Chris Speed

Nevertheless the disruptive nature of these interventions didn't go away and once the first prototype toilet roll holder was installed the family experienced further surprises. On one occasion during July 2014, whilst the family was on holiday far away from the toilet, the software engineer who developed the device contacted the author over telephone to tell him of fresh activity on the server. Following a quick conversation with his partner, the author concluded that the change in toilet roll coincided with the fortnightly visit of the house cleaner.

Such an event highlights the complex market that surround objects that are connected to the internet and distribute data. Although consent to gather data was acquired for the family, this is not the case for visitors to the house and in particular of users of the toilet. In addition to the ethical consequences, the event also highlighted the function that connected objects can have beyond sensing

the material that they are designed to. For the software engineer, the use of the toilet roll was an alert similar to that of a burglar alarm, and the data an indicator of an intruder.

The toilet roll holder and its connected database represent a suite of new technologies that are already available to buy. Whilst the brief summary of the social disruption that the toilet roll data has for a family is made clear due to the personal nature of toilet roll use, we should expect that all manner of conclusions may be drawn from even the most apparently benign sensor – from thermostat to toaster.



Figure 5. *First batch of instrumented toilet roll holders prior to distribution.* © Chris Speed

House as database

Living in a house that gains a shadow of itself in the form of data sets had begun to change the way that the author understands his family.

Not for a long time have I had to consider the toilet habits of my children or for that matter my wife. The last nappy I had to change was probably 5 years ago and soon after, the last of the nappy wipes was used up. Since then I have lost touch with when my children need the toilet, no longer do I have to smell them or ask them if they need to use the toilet. No longer do they even tell me when they need the toilet. The lack of this particular knowledge is

welcome and I haven't had to think about these particular practices for a long time. With a daughter of eight years of age and a son of eleven, the lock on the toilet door has been in regular use for four years now and everybody who uses it is secure in the fact that they have achieved a level of privacy, and that no one else needs to be aware of what goes on behind the closed door. But more recently things have changed.

With an accurate toilet roll sensor I now know when my family has used the toilet. The door that was previously locked tight shut has now opened just a little. As visitors come to the house I am now obliged to advise them that the downstairs toilet roll holder is online and that if they would prefer to use an upstairs toilet they are quite welcome. I have even begun to wonder if I should redact particular activity on the online graph when guests use toilet paper, or perhaps I should return their data to them on a memory stick when they leave the house. Certainly the toilet door now requires terms and conditions that should be agreed upon before entering.

On the up side I am beginning to learn more about the family's toilet paper habits and the software engineer who developed the technology is starting to explore opportunities for me to use the data in to inform living practices. The data in Fig 3. is beginning to offer information that is rich enough to begin programming alerts for me. For example, it appears that as the family runs out of toilet paper somebody places a half used toilet roll on to the holder, perhaps a sign of desperation. Chris Barker (software engineer) is able to identify this shift in data and organise a tweet to alert me to buy more toilet paper. Whilst a simple program for ordering toilet paper may not be so interesting, the important note is that the source of this data is not only personal to me, it is also owned by me. We built the toilet roll holder and I own the data. There are very few products or smart phone apps that I can say the same about. Usually I find myself agreeing to all manner of data agreements in order to get the 'free' software that is on offer. The toilet roll holder is then my first experience of producing data that I own and that I have the potential to begin to trade with. This awareness is the first step toward a significant turn in global economics – away from the established Push economy to a data driven Pull economy.

House as market place

The Push Economy, that dominated our experiences in the twentieth century, was predicated upon developing best guessed products that persisted by achieving a scale of production that secured a place on the shelves of supermarkets and a marketing budget to keep them there. As consumers we aspired to own well made products that were manufactured and distributed on a vast scale. A

model that suppressed poorly made products and presented high end artisan products as out of reach.

In stark contrast, the properties of the internet that define the Pull Economy are starting to offer a different model of success. Instead of occupying the middle ground of wealth creation through the large scale production of best guessed products, the Pull economy is characterised by boutique and bespoke products that define personal identity at one end of the scale, and cheap goods that let us make do and get by. This inversion of what we knew is led by the primary currency of the digital economy: data. But in the over hyped age of big data it is the agile and small organisations that have been able to develop more nuanced approaches to nurturing value for data with individuals. As the big firms figure out what to do with the vast amount of data that gathers on a minute by minute basis, micro businesses are tackling small data to create high value experiences.

It is in the small business ideas that people are beginning to be offered 'value for their data' which is setting the agenda for the digital economy and placing pressure on the established organisations that previously claimed to manage our best interests with generic models. Fitbit have led the charge within the quantified self movement, providing owners with access to software to monitor their own health, Halo have refined the taxi market and Uber promises to break it, whilst SkyScanner has unlocked the flight booking business and redefined it.

Core to all of these successes to date is the wide spread adoption of the smart phone and it's constant connection to the internet and complex instrumentation, the flow of data that is promoted through the adoption of apps that contextualise data, and the data value constellations that move data between parties to construct richer experiences. So we can be sure that the smart phone has extended the complexity of the economics of data. But what happens when the same affordances are extended to our domestic products?

If domestic appliances follow the same model of trading our data through the availability of free apps and undecipherable terms and conditions then we can expect that much more of our lives will become available as a database for enquiry. Unless individuals know that they own their own data, companies who offer services will need to offer relevant services and products that are commensurate with the expectations of the public as data becomes the primary currency within transactions.

As our homes move alongside smart phones to become the new market place for organisations to better understand our activities, a critical question for artists and designer will become more prominent: how to design systems that offer value for data. Whilst the toilet roll holder is a small step along the path toward a push economy, for the first time I own the data and can begin to use it to inform my own buying habits.

As society moves from a Push economy to a Pull economy, the toilet roll holder is a small piece of vital research that is required to better understand how to support the public's understanding of the trading of personal data, and the appropriate interfaces (material/immaterial) in gaining control.

Discussion

The implications for how the Internet of Things will impact upon our daily practices is beginning to be understood through the examples of how data might be used to change the value of goods, and the potential for individuals to trade personal data. Heralded as the next paradigm of the internet, the connected objects that collect data as we go about doing 'things' are core to the development of new kinds of markets that will define our relationship with cloud services. Never entirely clear how the products that represent our incentives to give data away are funded, or what companies do with our data once we enter an agreement, how we use things is already part of a complex web of data-value-constellations in which we hope to feel that we are getting both value for our money and value for our data.

Prototype technologies such as the connected toilet roll holder demonstrates the level of social disruption that is likely to occur as it becomes increasingly likely any personal information can be identified through the correlation of data from multiple sensors.

The aim of the project is not simply to provide people with *more information*, but rather to explore *new cultural practices* with a view of instigating behavioural change around the valuation of data. The toilet roll holder demonstrates the complex roles of participation within complex production of data.

This paper asserts that markets that involve objects within social practices that, along with the algorithms of the stakeholders involved, mediate values to keep the market sustainable. Participants in such markets should consider the implications of the experiences that constitute the trading of values, from the personal to the social, and the economic to the environmental.

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